Fifth Quarterly Report

Date of Report: August 2, 2006

Contract Number: DTRS56-04-T-0007

Prepared for: U.S. Department of Transportation, Office of Pipeline Safety Research and Development

Project Title: Infrasonic Frequency Seismic Sensor System for Preventing Third Party Damage to Gas Pipelines

Prepared by: NYSEARCH/Northeast Gas Association

For three quarterly periods ending: June 30, 2006

I. LIST OF ACTIVITIES AND DELIVERABLES COMPLETED DURING THIS REPORTING PERIOD BY TASK NUMBER

Task	*Activity/Deliverable*	*Payable Milestone Title*	*Due – months after award*
3.5	Utility Product Requirements - NYSEARCH	System specs (2nd generation) developed by utility personnel	9 – Completed month 14 with exchange and confirmation of interface with GasNet specs
4.1	EP-2 Checkout & Field Test; refine algorithms	Lab Testing of 2nd Generation System	13 - Completed
5.1	Define AP Specifications	Deliver AP Specifications & Requirements Document	Incomplete – this task needs to be undertaken after recommendations and tasks from Independent Consultant's issues are addressed
5.3	NYSEARCH Project Management	Self Explanatory	12 - Completed
5.4	Quarterly Status report - #5 (in lieu of Final Report because of pending contract extension)	Fifth quarterly report and following months to contract extension completed with this submittal	12 - Completed with this Submittal

PUBLIC PAGE

During the period from 1 Oct 05 to 30 June 06, PSI and NYSEARCH have been working on the following tasks for the PIGPEN sensing program: 1) Utility Product Requirements, 2) Lab Testing of 2nd Generation (EP-2) System, 3) Field testing of EP-2 system, and, 4) Analysis of the Independent geophysical consultant's recommendations.

PSI focused on testing of the EP-2 system during the fifth and last formal quarter of this funded project. In subsequent months, PSI had discussions with all involved parties, including the independent consultant and experts that the consultant recommended on issues related to the ability of this system to meet industry specifications for location accuracy. PSI accepted the recommendations and has proposed additional activities to address this area.

During this period, NYSEARCH held internal reviews to make a determination on its level of support and recommended emphasis going forward. Also, NYSEARCH and PSI worked on product utility requirements and interfacing issues between the damage prevention application of this technology with the real time sensing platform that NYSEARCH has developed known as Gas Net™. NYSEARCH Staff also participated in field tests in the Andover, Ma. test area that PSI has access to. Also, NYSEARCH worked with PSI and the independent consultant to define tasks to address concerns about location accuracy.

This project is expected to continue for two more quarters under a modification to the existing agreement.

During the extension period, PSI is proposing to perform the following tasks:

- Incorporate geophysical modeling components into the overall system model for optimal performance in complex soil conditions
- Conduct additional field testing of the PIGPEN system in complex soil conditions

During the extension period, NYSEARCH is proposing to perform the following tasks:

- Work with PSI, the independent consultant and industry supporters to ensure that test conditions address concerns
- Communicate results and issues to all involved parties

A. Technical Status

During the period of October 1, 2005 through June 30, 2006 program work focused on:

1. EP-2 Field Checkout and Field Test

Repaired and redeployed the EP-1 sensor network at the Andover, MA site

One of the EP-1 sensors suffered water infiltration after heavy rains at the test site. While the package is hermetically sealed and weathertight, there is a hermetic feedthrough for the power and signal wires (Figure 1). The wire bundle diameter was at the minimum specified size for the hermetic feedthrough. Upon disassembly and inspection, PSI found that the feedthrough grommet had been crimped during installation. Water infiltrated along the crimp, found its way to the electronics board and caused a component failure on that board.

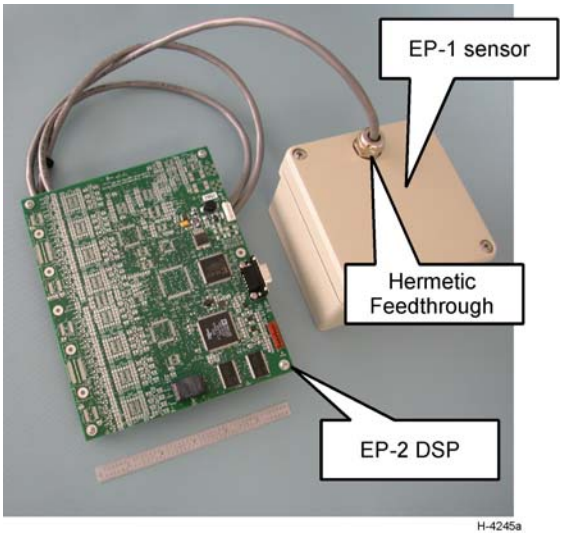

Figure 1. PIGPEN EP-1 sensor head and EP-2 prototype processor.

None of the other PIGPEN sensors suffered from water infiltration.

To eliminate this problem, PSI increased the size of the wire bundle to be in the middle of the specified size range for the feedthrough. PSI also conformally coated the electronics boards to prevent shorting in the unlikely event of water infiltration or condensation.

Two of the other sensors suffered damage to their above-ground wire bundles due to unanticipated equipment activity at the site. PSI repaired and redeployed all the sensors.

Due to the repairs and inclement PSIather during October, PSI did not acquire any additional field data.

2. Continue to refine the EP-2 threat identification algorithms

To better reject false positives due to backgrounds, PSI incorporated a user-set threshold into the identification algorithm. That threshold was successful at eliminating false positive detections.

3. EP-2 Field Test

PSI conducted fielding testing of EP-2 at a site near PSI on 21 November 2005. NYSEARCH personnel witnessed the testing. PSI used a jackhammer located at 50 yd, 100 yd and 200 yd. In all cases, the EP-2 correctly identified the threat.

4. Utility Product Requirements

One of the goals for defining the utility interface concepts is to insure that the specifications for the interface are common to other gas utility monitoring technologies. One such technology, which is at the pre-commercial stage and that fits well with PIGPEN, is the NYSEARCH-developed GASNET real-time sensing NYSEARCH's involvement in PIGPEN, the funders have directed NYSEARCH Staff to develop common interface standards. So in accordance with that guidance, our GASNET project manager, Dr. George Vradis, spent time reviewing the PIGPEN project and has participated in the two Design Review meetings.

In order to assess the ability to integrate the PIGPEN sensors into the GasNet infrastructure, NYSEARCH requested the following information:

- Sensor output protocol. The current configuration on GasNet for the external sensor hookup is RS232 format.

PIGPEN is baselining RS485 as something of an industry standard for SCADA networks. On the PIGPEN side, RS232 is compatible with RS485.

- Power requirements of sensor for different modes of operations in terms of frequency of signal acquisition, alarms strategy, etc.

Quiescent power is 50 mW. Peak power is 1W. If PSI assume a duty cycle (1%, 10% etc) or fraction of time that the system detects a potential source, then PSI can create a simple power model.

100% duty cycle:	1W
10% duty cycle:	150 mW
1% duty cycle:	60 mW

- Wiring size and wire jackets. Any limits on what you need to have or can it be what GasNet would like (Teflon jacket or PDC). What is the size of the wires?

Based on current rating and voltage drop considerations 26 ga is probably a reasonable minimum, although PSI could go smaller. At max power (1 W or roughly 100 mA at 12 V), the voltage drop over 150 ft of cable is 0.6 V.

- Size of electronics to accompany the sensor.

Each 5x5x3.5 inch sensor carries its own electronics. In addition, there is a second processor box for every 16 sensors (also 5x5x3.5 inch).

5. Additional Work conducted in the period of January 1, 2006 through June 30, 2006

PSI and NYSEARCH discussed plans for extending the work for numerical modeling and field tests in complex soil conditions to address concerns and independent consultant's recommendation regarding location accuracy.

PSI prepared a draft white paper describing the rationale for the additional work as well as the work proposed. The full draft white paper is included in the Appendix.

B. Business Status – Discussions with Operators, or Potential Users of Technology Under Investigation

NYSEARCH Users were present at the September 21 Design Review meeting as well as the Staff update that was provided at the NYSEARCH committee meeting in June. On both occasions, discussions focused in two areas: 1) concern about location accuracy, and, 2) planning and identification of prospective commercial partners (NYSEARCH users have critiqued the Staff list of prospective commercial partners and have added/deleted company names to the list.).

C. Payable Milestones – Completed During the Reporting Period

As noted on p.1, there were several tasks completed during the fifth quarter and one task that was deferred as a result of new issues and the proposed new work. The tasks that were completed were 3.5, 4.1, 5.1, 5.3 and 5.4.

II. RESULTS AND CONCLUSIONS (INCLUDING FINDINGS, DISCOVERIES, AND ATTACHMENTS OF ANY TEST DATA AND/OR PICTURES)

1. EP-2 Field Tests

The tests at an empty lot near PSI involved use of a jackhammer located at 50 yd, 100 yd and 200 yds. There were no false positive and no misidentifications (see Figures 2 through 7). The field test demonstrates the real-time processing capabilities of the PIGPEN system.

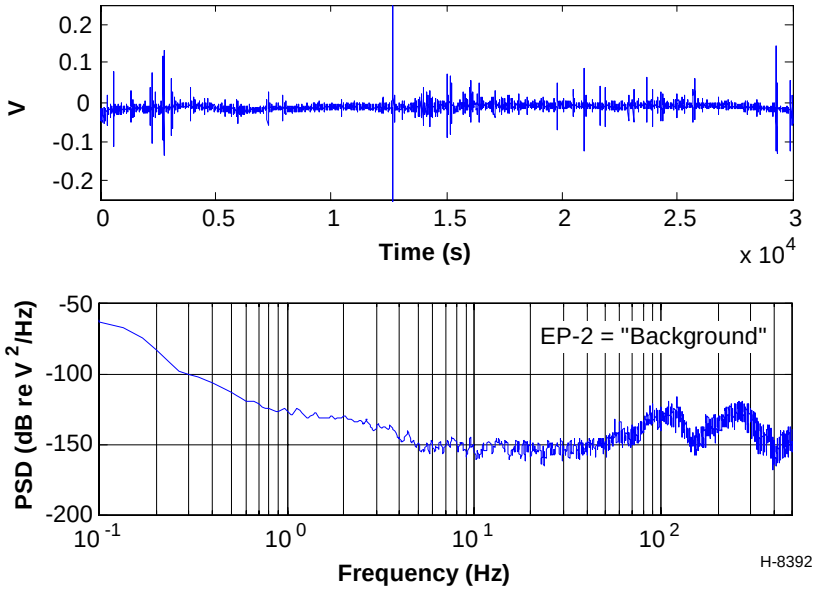

Figure 2. EP-2 test; 50 yards; no threat.

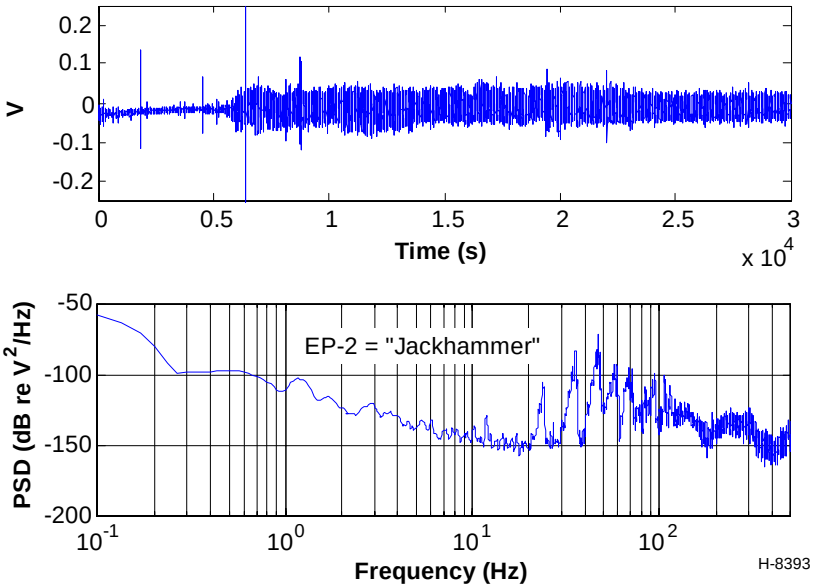

Figure 3. EP-2 test; 50 yards; jackhammer on.

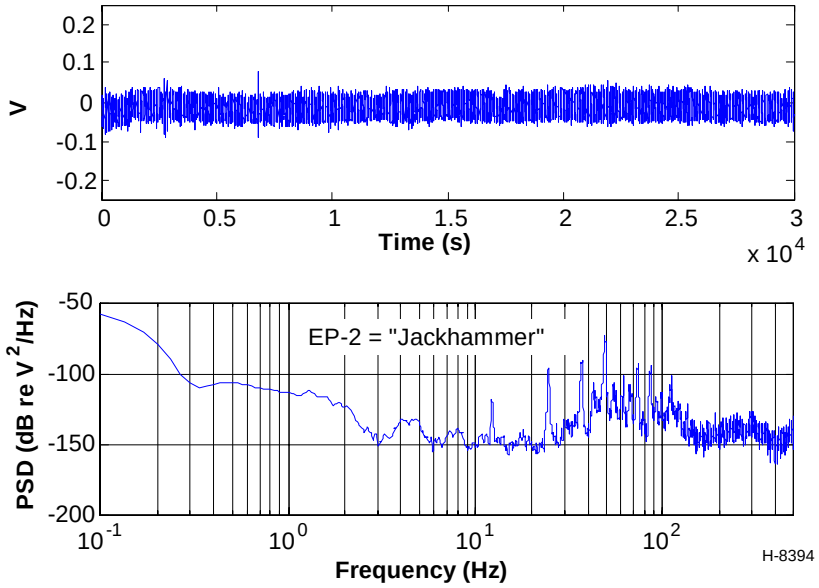

Figure 4. EP-2 test; 50 yards; jackhammer on.

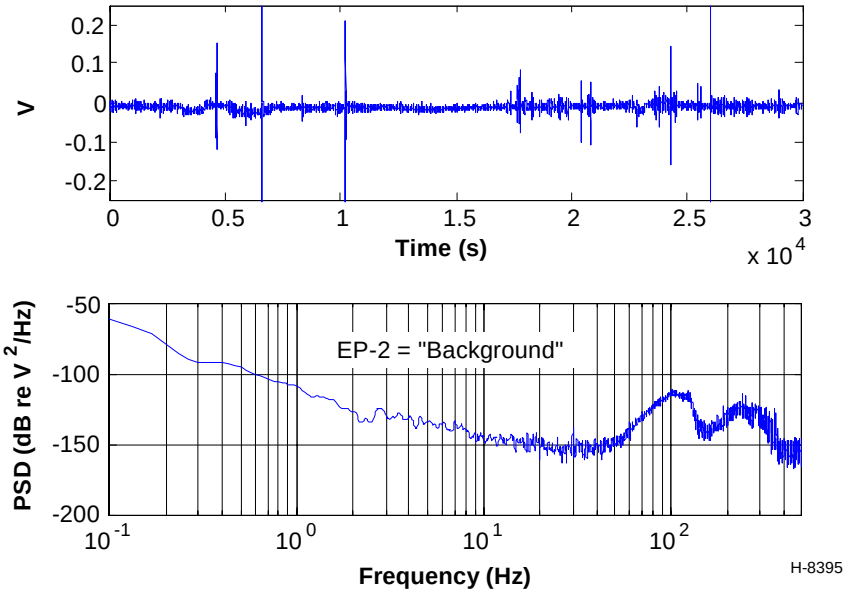

Figure 5. EP02 test; 200 yards; no threat.

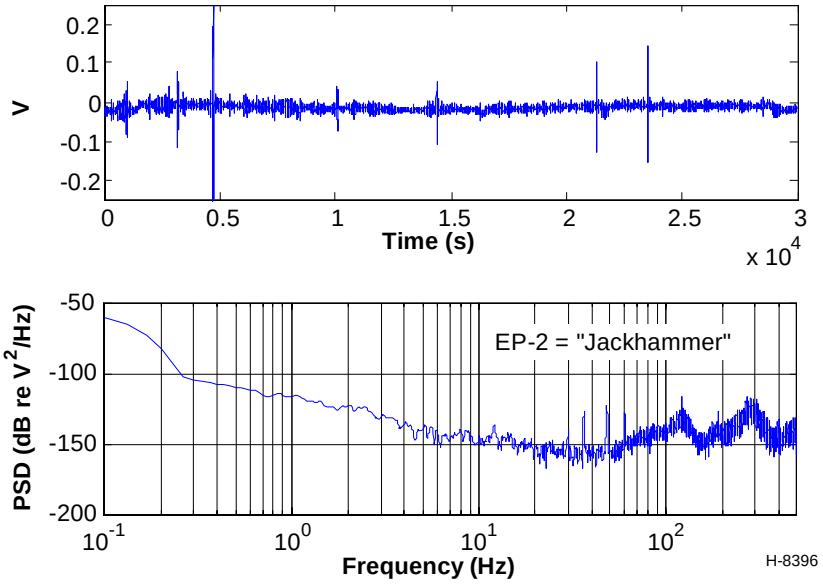

Figure 6. EP-2 test; 200 yards; jackhammer on.

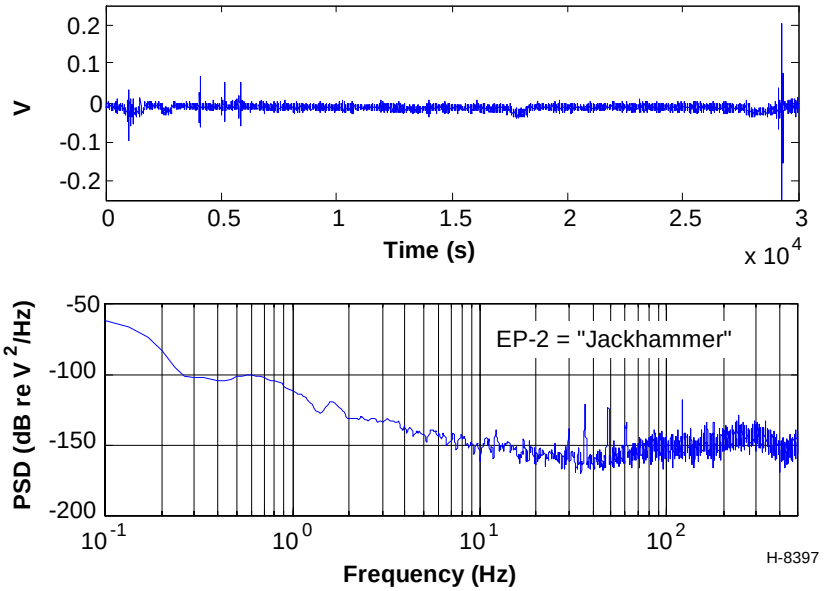

Figure 7. EP-2 test; 200 yards; jackhammer on.

2. NYSEARCH Assessment of Steeples' Recommendations and Overall Results

Following a review meeting by the project sponsors on September 21 and submission of the full Steeples' report to the sponsors, a conference call was held on October 19 to review issues and recommendations provided by the Independent Consultant, Don Steeples. As a result of that call, the NYSEARCH sponsors feel that the location accuracy target that they originally specified of 10 yards with 300 yard sensor spacing will be difficult to meet and that this result

lessens the applicability of the technology to their jobs. Therefore, the NYSEARCH sponsors determined that they do not want to pursue additional new work on this system until the issues that Steeples has identified, such as the need to understand accuracy in complex soil conditions and the need for numerical modeling are addressed by PSI. [PSI has stated that no existing tests or planned project tests address the issue. They would need to apply at least 4 sensors but possibly up 8 sensors in a field test in complex soils. This equipment is not available through the current contract with NYSEARCH and OPS nor is it funded through the separate PSI SBIR award received from DOT.] This position has prompted PSI to propose an extension to the contract and additional work.

3. NYSEARCH Staff Observations from EP-2 Field Test

During the tests conducted with the EP-2 system in Andover in an empty test lot near the PSI facility, D'Zurko and Janega of NYSEARCH attended the tests. One concern raised from that test activity is that a limited variety of construction equipment has been tested each time; in this test, it was just a jackhammer. In the tests on the EP-1 system in April 2005, there were only 2-3 types of equipment (e.g. backhoe and jackhammer). Through other NYSEARCH programs on damage prevention where signatures were captured by sensors after impacts in the ground, field tests that used a wide range of construction equipment showed that results varied with type of equipment and soil type. As a result of this concern prompted by the November EP-2 tests, D'Zurko has been seeking additional field tests from sponsors to get other equipment activities and corresponding data. Since November, members have been notified of this concern. In particular, one member was contacted multiple times because of their interest and they have not produced an applicable job. Once the project is re-started, additional NYSEARCH supporters will be contacted.

4. PSI's Assessment of Steeples' Concerns and Status of Response

NYSEARCH's geophysical consultant has raised several issues regarding triangulation accuracy under complex geological conditions. PSI acknowledges these issues and has had discussions with NYSEARCH and the consultant regarding techniques for improving accuracy in the field.

The basic problem is illustrated in Figure 8. Surface waves refract at interfaces of differing soil types leading to erroneous calculation of source location.

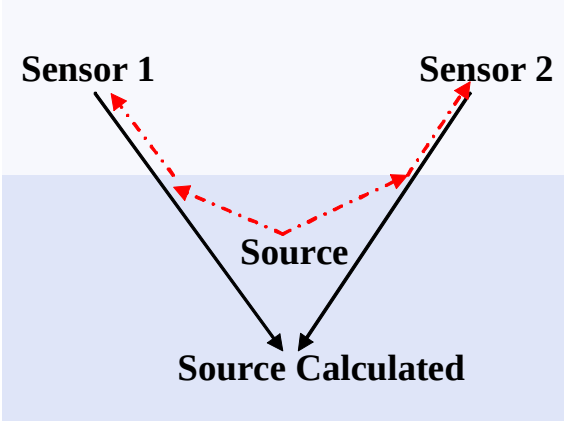

Figure 8. Surface waves refract at interfaces of differing soil types leading to erroneous calculation of source location.

In order assess these effects on PIGPEN performance and to develop means of compensating for these effects, PSI suggested the following activities for future programs.

1. Investigate use of the air-coupled wave to augment triangulation determinations.
2. Consider the benefit of simple site characterizations during PIGPEN installation to coarsely characterize the velocity fields.
3. Develop a controlled field test specifically to address the question of complex geology on PIGPEN performance.
4. Develop a numerical model to predict system performance, to guide field test planning and to guide system development.

Under its existing program PSI has already undertaken investigation of air-coupled waves to augment triangulation determination. PSI are also developing more complex triangulation algorithms that can incorporate site characterization calibrations. PSI have also already begun modeling of the triangulation accuracy to predict system performance.

PSI proposes additional activities to address the remaining recommendations made by NYSEARCH's geophysical consultant:

- Incorporate geophysical modeling components into the overall system model to address PIGPEN performance in complex soil conditions
- Conduct additional field testing to address PIGPEN performance in complex soil conditions

In February 2006, as part of the attempt to define the numerical modeling piece described in #4 above, PSI had discussions with George McMecham of UT-Dallas; an expert who has done similar modeling and who was recommended by Steeples. PSI also provided sample data to McMecham to aid the discussion and define the modeling plan.

III. PLANS FOR FUTURE ACTIVITY: (INCLUDING POTENTIAL MEETINGS, TESTS, AND/OR DEMONSTRATIONS SCHEDULED OVER THE NEXT QUARTER)

Given the additional proposed work, there are no approved future activities until that proposal is addressed. It is acknowledged that under the existing contract, a Final Report is still outstanding.

Appendix A

WP06-07

Proposal for PIGPEN Testing in Complex Soil Conditions

Prepared for:

DOT/Office of Pipeline Safety

And

NYSEARCH/NGA

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28 March 2006

1. Introduction

With funding from NYSEARCH/NGA and the Department of Transportation's Office of Pipeline Safety, Physical Sciences Inc. has been developing the Proactive Infrasonic Gas Pipeline Evaluation Network (PIGPEN). PIGPEN is a spare network of seismic sensors that protect gas pipeline infrastructure by detecting, identifying, and locating potential third-party threats.

During the course of the recently completed Experimental Prototype (EP) development program ("Infrasonic Frequency Sensor System to Prevent Third Party Damage to Gas Pipelines"), PSI completed the following tasks:

1. Develop EP sensor head and analog electronics.
2. Establish performance of EP sensor head, analog electronics and preliminary algorithms through field testing.
3. Refine EP design. Refine sensor head and analog electronics. Develop final version hardware. Refine algorithms and implement on an EP digital signal processor (DSP) that is consistent with the form factor and design limitations of the PIGPEN system.
4. Establish performance of EP PIGPEN system through acquisition of field test data.
5. Work with NGA to identify and appropriate commercialization partner.
6. Establish requirements and specifications for the Alpha Prototype PIGPEN sensor and system.

During the course of the EP program PSI demonstrated the following technical performance:

- Detect realistic threats under field conditions at ranges >500 m.
- Differentiate representative threats (backhoe and jackhammer) in real time with an automated processing algorithm implemented on a digital signal processor compatible with PIGPEN physical specifications.
- Locate threats (impacts and jackhammer) with an average accuracy of roughly 3 m at a range of 150 m in uniform soil conditions.

As part of the EP development effort, NYSEARCH retained a geophysicist to act as an independent technical consultant (Dr. Don Steeples). He and NYSEARCH have expressed concern about PIGPEN's ability to triangulate threats in complex soil conditions. Therefore, PSI propose to plan and execute a field test designed specifically to characterize PIGPEN's performance under complex soil conditions.

2. Triangulation Measurements

During the EP program, PSI demonstrated basic triangulation performance and accuracy. PSI deployed four sensors at a site near PSI's Andover location. That site is an empty building lot roughly 250 m x 250 m in size. Figure 1 shows an aerial view. The red stars represent the sensor locations.

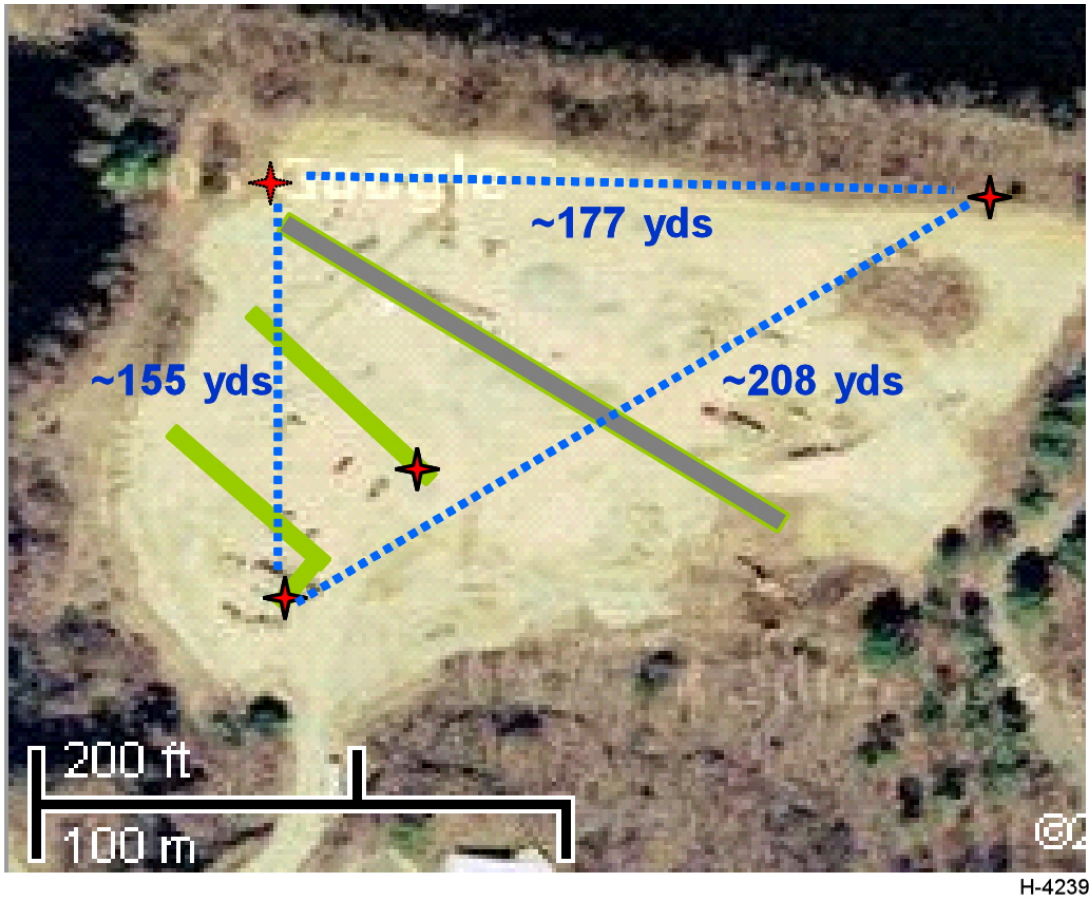

Figure 1. Aerial view of Andover field test site.

At that site, PSI acquired triangulation data using a sledgehammer and a jackhammer as sources located at several positions. The sensor and threat positions are surveyed with an accuracy of +/- 1 yard.

For each threat location, PSI process the time series data from three to four sensors to determine the triangulated position. Table 1 summarizes the results. The triangulated positions are determined with a precision of +/- 1 yd. The accuracy of the triangulated positions is +/- 3.5 yards at a nominal range of 150 yards. The position

accuracy varies from 1 – 9 yards. The triangulated jackhammer location has same accuracy as sledgehammer location.

Table 1. Summary of Triangulation Measurement Results

	Surveyed (+/- 1 yd)		PIGPEN Measurement	
	X	**Y**	**X**	**Y**
Sledgehammer - U	24.7 yd	23.4 yd	27.8 ± 0.8 yd	25.9 ± 1.1 yd
Sledgehammer - V	65.1 yd	47.9 yd	64.4 ± 1.4 yd	53.5 ± 1.0 yd
Sledgehammer - X	125 yd	-4.5 yd	128 ± 0.6 yd	4.2 ± 1.0 yd
Jackhammer	-22.5 yd	62.4 yd	-18 ± 1.0 yd	64 ± 1.0 yd

The triangulation specification articulated at the beginning of the EP program was 10 m accuracy at a range of 300 yards. That specification was derived from an angular accuracy; therefore it translates into 3.3 yards at a range of 100 yards (or 33 yards at a range of 1000 yards). From these data, PSI conclude that the PIGPEN inherent triangulation accuracy (3.5 yards at 150 yards range) meets the specification.

3. Interaction with Geophysical Consultant

NYSEARCH's geophysical consultant has raised several issues regarding triangulation accuracy under complex geological conditions. PSI acknowledge these issues and have had discussions with NYSEARCH and the consultant regarding techniques for improving accuracy in the field.

The basic problem is illustrated in Figure 2. Surface waves refract at interfaces of differing soil types leading to erroneous calculation of source location

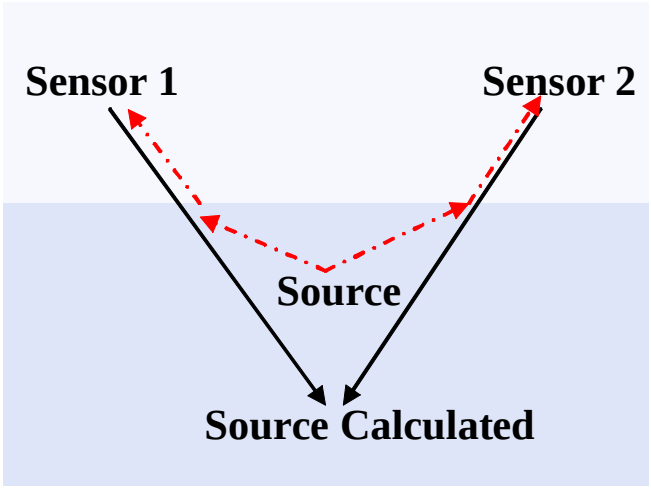

Figure 2. Surface waves refract at interfaces of differing soil types leading to erroneous calculation of source location.

In order assess these effects on PIGPEN performance and to develop means of compensating for these effects, PSI suggested the following activities for future programs.

1. Investigate use of the air-coupled wave to augment triangulation determinations.
2. Consider the benefit of simple site characterizations during PIGPEN installation to coarsely characterize the velocity fields.
3. Develop a controlled field test specifically to address the question of complex geology on PIGPEN performance.
4. Develop a numerical model to predict system performance, to guide field test planning and to guide system development.

4. Proposed Activities

Under its existing program PSI has already undertaken investigation of air-coupled waves to augment triangulation determination. PSI are also developing more complex triangulation algorithms that can incorporate site characterization calibrations. PSI have also already begun modeling of the triangulation accuracy to predict system performance.

PSI propose additional activities to address the remaining recommendations made by NYSEARCH's geophysical consultant:

- Incorporate geophysical modeling components into the overall system model to address PIGPEN performance in complex soil conditions
- Conduct additional field testing to address PIGPEN performance in complex soil conditions

PSI estimate that this effort would require 4-6 months to complete.

4.1 Proposed Geophysical Modeling

NYSEARCH's geophysical consultant identified two academic research groups who perform geophysical modeling. PSI have contacted Prof. George McMechan at University of Texas, Dallas regarding the modeling. Prof McMechan's group has a wide variety of seismic modeling capabilities for almost every conceivable geophysical situation. PSI will work with Prof McMechan to define a few modeling cases that will provide insight into PIGPEN performance under a wider variety of soil conditions. As examples:

- Case 1. Represent a more or less uniform soil condition that closely matches conditions for which PSI already have test data (e. g., Andover, MA, or Johnson City, NY).
- Case 2. Model Case representing the test conditions for future complex soil testing. PSI can then compare the model predictions to future field test data
- Cases 3 & 4. Stressing cases for PIGPEN performance

4.2 Proposed additional field testing

PSI propose a field test specifically designed to address the issues of performance in inhomogeneous soils, per the discussions with NYSEARCH and their geological consultant.

Figure 3 shows the schematic field test configuration. PSI would deploy at least 4 EP-1 type PIGPEN sensors (8 preferred) over a site that has non-uniform, but PSIll characterized soil conditions. PSI would deploy threats at multiple locations and measure synchronized time-series data from each sensor. Using those data, PSI will:

- Assess the performance of the existing PIGPEN triangulation algorithm.
- Develop compensation techniques (as discussed previously) to improve triangulation accuracy.
- Validate the error model

Table 2 summarizes the test plan.

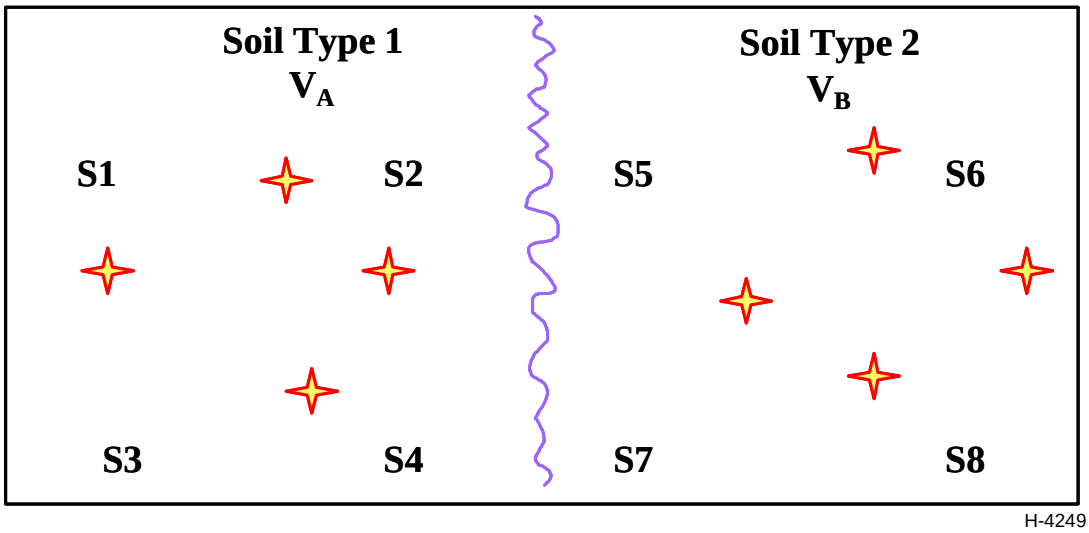

Figure 3. Schematic configuration of the proposed complex soil condition field test.

Site Requirements

- Size: 1000 m x 500 m ideal; 500 m x 100 m minimum
- Soil: two regions of characterized soil having different velocities

Sensor Requirements

- 8 PIGPEN EP-1 sensors (4 sensors minimum)
- hard-wired data acquisition system that ensures absolute sensor synchronization
- sensor and threat locations surveyed to within +/-1m

Threats

- Gas-poPSIred soil tamper (minimum)
- Backhoe
- Jackhammer

Table 2. Test Plan Summary

DAY 1	Survey site Survey sensor and threat locations Deploy sensors
DAY 2	Deploy sensors Sensor and data acquisition system checkout

	Site characterization measurements
DAY 3	Acquire data using tamper Assess air-coupled contribution Data assessment
DAY 4	Acquire data using additional threats
DAY 5	Extra day Retrieve equipment

In order to accomplish our test objectives, PSI will execute the following tasks

1. Work with NYSEARCH's geophysical consultant and other experts to identify a suitable test site.
2. Work with NYSEARCH's geophysical consultant to develop a detailed test plan.
3. Schedule and execute the test at the test site per the test plan.
4. Analyze the data to assess the performance of the present PIGPEN system.
5. Assess the performance of techniques that compensate for the complex soil conditions.

4.3 Cost and Schedule

4.3.1 SOW

1. Perform geophysical modeling as part of systems modeling.
2. Conduct additional field testing to address complex soil effects.

4.3.2 Cost

$35 K

4.3.3 Schedule

6 months